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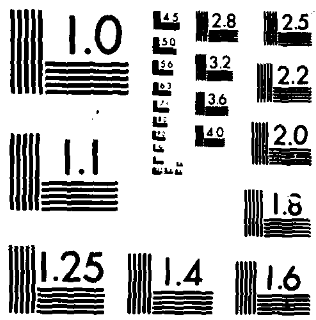

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TECHNICAL NOTE NO. 3-85

TIMING OPTIONS FOR FKN PHASE I PORTION OF DEB

FEBRUARY 1985

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

AD-A165284

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY: N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): DCEC-TN 3-85	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: Defense Communications Engineering Center — 6b. OFFICE SYMBOL (If applicable): R220	7a. NAME OF MONITORING ORGANIZATION: N/A
6c. ADDRESS (City, State and ZIP Code): 1860 Wiehle Avenue, Reston, VA 22090	7b. ADDRESS (City, State and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Defense Communications Engineering Ctr — 8b. OFFICE SYMBOL (If applicable): R220	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State and ZIP Code): 1860 Wiehle Avenue, Reston, VA 22090	10. SOURCE OF FUNDING NOS. N/A
11. TITLE (Include Security Classification): Timing Options for FKN Phase I Portion of DEB (Unclassified)	PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT NO.

12. PERSONAL AUTHOR(S): Thomas L.McCrickard, III, Walter J. Cybrowski, Jr.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Technical Note	FROM ______ TO ______	February 1985	20

16. SUPPLEMENTARY NOTATION: Review for relevance 5 years from submission

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	synchronization, plesiochronous, clock distribution subsystem, asynchronous, pulse stuffing, troposcatter, time division multiplexing

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A number of timing and synchronization alternatives exist for the implementation of the digital transmission equipment for Frankfurt North Phase I. Based on performance considerations, each alternative is discussed separately, prioritized, and a final recommendation made.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL: Thomas L. McCrickard, III	22b. TELEPHONE NUMBER (Include Area Code): (703) 437-2787 — 22c. OFFICE SYMBOL: R220

DD FORM 1473, 83 APR — EDITION OF 1 JAN 73 IS OBSOLETE.

SECURITY CLASSIFICATION OF THIS PAGE

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TIMING OPTIONS FOR FKN PHASE I PORTION OF DEB

FEBRUARY 1985

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FOREWORD

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EXECUTIVE SUMMARY

This report discusses timing and synchronization (T&S) options for the Frankfurt North (FKN) Phase I portion of the Digital European Backbone (DEB). Also described is the criteria used in planning the network T&S capability for the planned digital upgrade of the FKN Phase I. The underlying purpose of the report is to identify the various available T&S options and make recommendations based on system performance considerations.

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I. INTRODUCTION

Timing and Synchronization (T&S) is required within the Frankfurt North (FKN) Phase I (shown in Figure 1) portion of the Digital European Backbone (DEB) to: (1) allow synchronous transmission within the low speed digital data network, (2) provide acceptable performance of digital troposcatter by using synchronous interfaces for all levels of multiplex, and (3) provide extension of satellite derived synchronous circuits into the terrestrial DCS. Widespread application of the Low Speed Time Division Multiplexer (LSTDM) and its synchronous data channel capability will require this T&S capability. The introduction of digital troposcatter will require synchronization of associated equipment. The network of digital switches and interconnecting digital trunks being implemented as the European Telephone System (ETS) must also be synchronized [1].

In addition to these near term requirements described above, there exist long term requirements for, and benefits to be derived from, a timing and synchronization subsystem. Benefits to be derived are improved performance, efficiency, and availability of digital transmission links and the potential for dissemination of precise time/frequency to other users. An improved timing capability will also aid in establishing or reestablishing communications, reduce the time to acquire synchronization of a spread spectrum signal that is being jammed, and facilitate the synchronization of crypto equipment.

Figure 2 depicts the Government-owned transmission facilities that will be used to implement Frankfurt North Phase I. Digital channels are provided for the Data Transmission Network (DTN) by the Low Speed Time Division Multiplexer (LSTDM), which interfaces with the low speed data circuits and time division multiplexes them into data trunks (usually at 56 or 64 kb/s). The data trunks and medium speed data users are provided digital channels by first level multiplexers, the AN/FCC-98, using a multirate synchronous data channel module. These data channels are multiplexed into digroups (1.544 Mb/s) along with voice signals that have been digitized using pulse code modulation (PCM). These digroups are multiplexed by the AN/FCC-99 (second level multiplexer) into mission bit streams (MBS) at 3.232, 6.464, 9.696, or 12.928 Mb/s for internodal transmission.

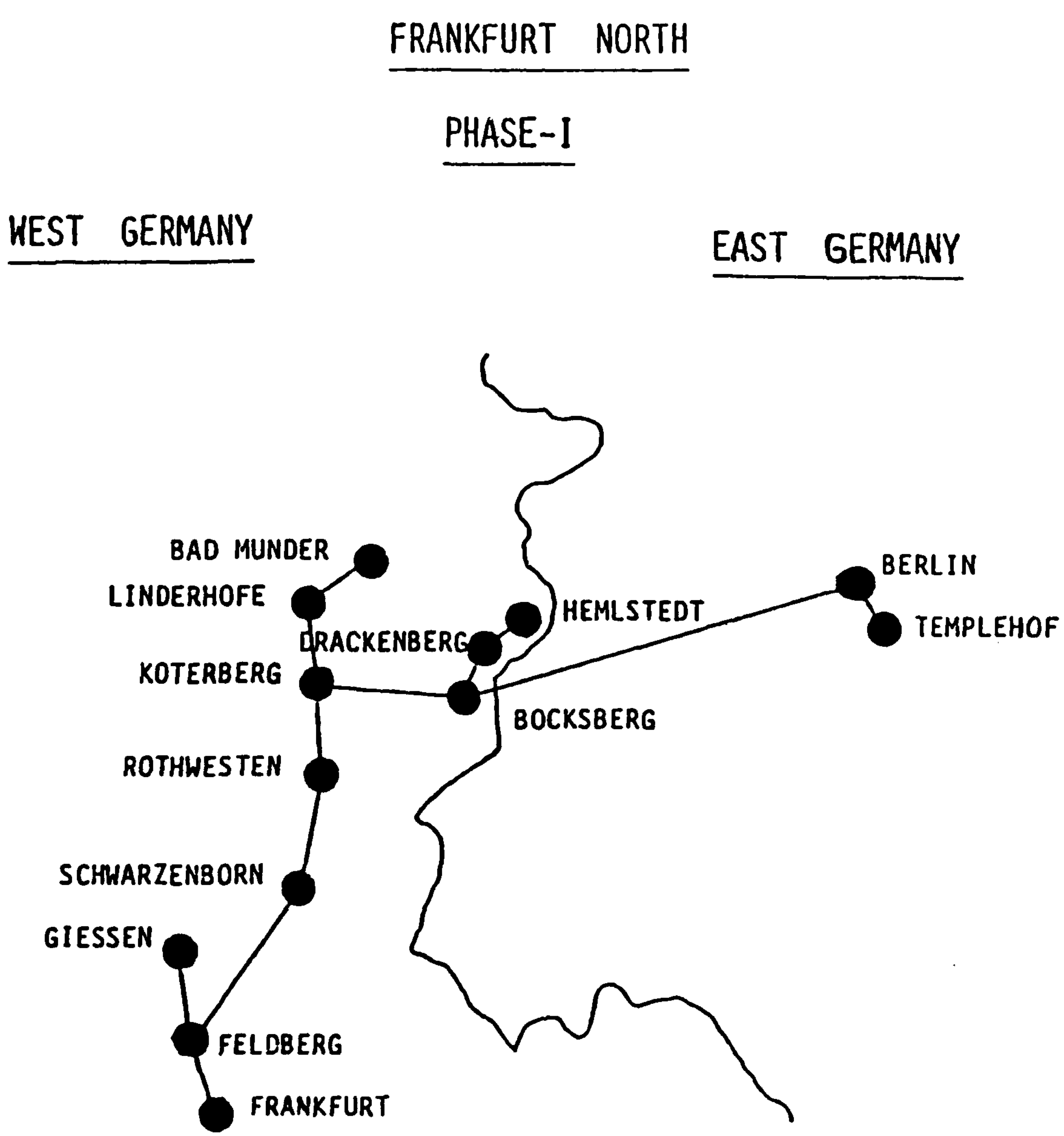

Figure 1. Frankfurt North Phase I Configuration.

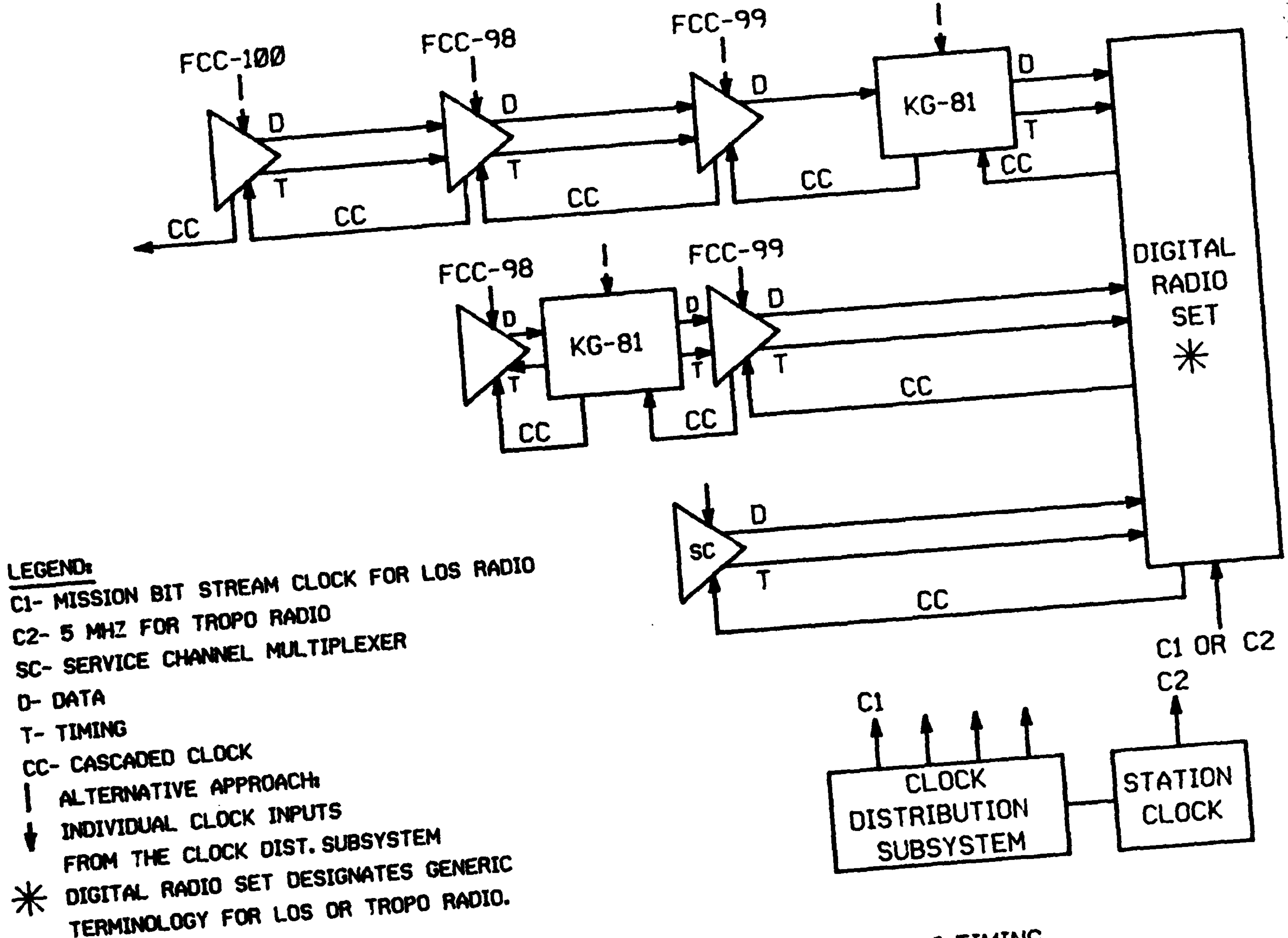

FIGURE 2. TYPICAL FRANKFURT NORTH PHASE I TIMING AND SYNCHRONIZATION CONFIGURATION.

II. REQUIREMENTS

The basic requirement for the timing configuration used in this digital system is to minimize loss of bit count integrity (LBCI). This basic requirement should be met under both optimum and degraded system conditions (i.e., equipment failure and severe radio channel fading). Reference 2 provided the initial LBCI allocations for the recommended interim DCS plesiochronous timing configuration based on Loran-C. Reference 3 restated the LBCI requirements in terms of Mean Time to LBCI (MTTLBCI) for the revised Hypothetical Reference Circuits (HRC's). From reference 3, the MTTLBCI requirements for a single LOS hop is 113 days, and for a single tropo hop is 14 days. Applying these requirements to the two worse case (longest) digroup connectivities, see Figures 1 and 3, results in the following allocations: for the Berlin-Frankfurt tandem connection of 1-tropo plus 5-LOS hops, 8.4 days; for the Helmstedt-Frankfurt tandem connection of 7-LOS hops, 16.1 days. As discussed in section IV, the choice of the FKN Phase I timing configuration will play a major role in the ability to meet these system requirements.

III. NETWORK

Figure 1 shows the geographical connectivity of FKN Phase 1. In Figure 3, the connectivity of the first level multiplexer digroups is shown. Information on the number of digroups that traverse both the Bocksberg-Berlin tropo link and the LOS links was derived from these figures and is used in the analysis and recommendation sections of this report (sections IV and V).

It is important to note that several digroups originating/terminating in Berlin continue through the system south to Frankfurt. This connection involves a single tropo plus 5 tandem LOS hops. Due to the burst error nature of troposcatter, the resulting end-to-end BCI performance of this connection will be mainly determined by the tropo hop [4,5,6], especially for the looped and asynchronous timing options discussed in section IV. This burst error performance degradation aspect becomes even more critical when the tropo hop is operating on dual diversity (rather than quad diversity) due to, for example, the failure of one High Power Amplifier (HPA).

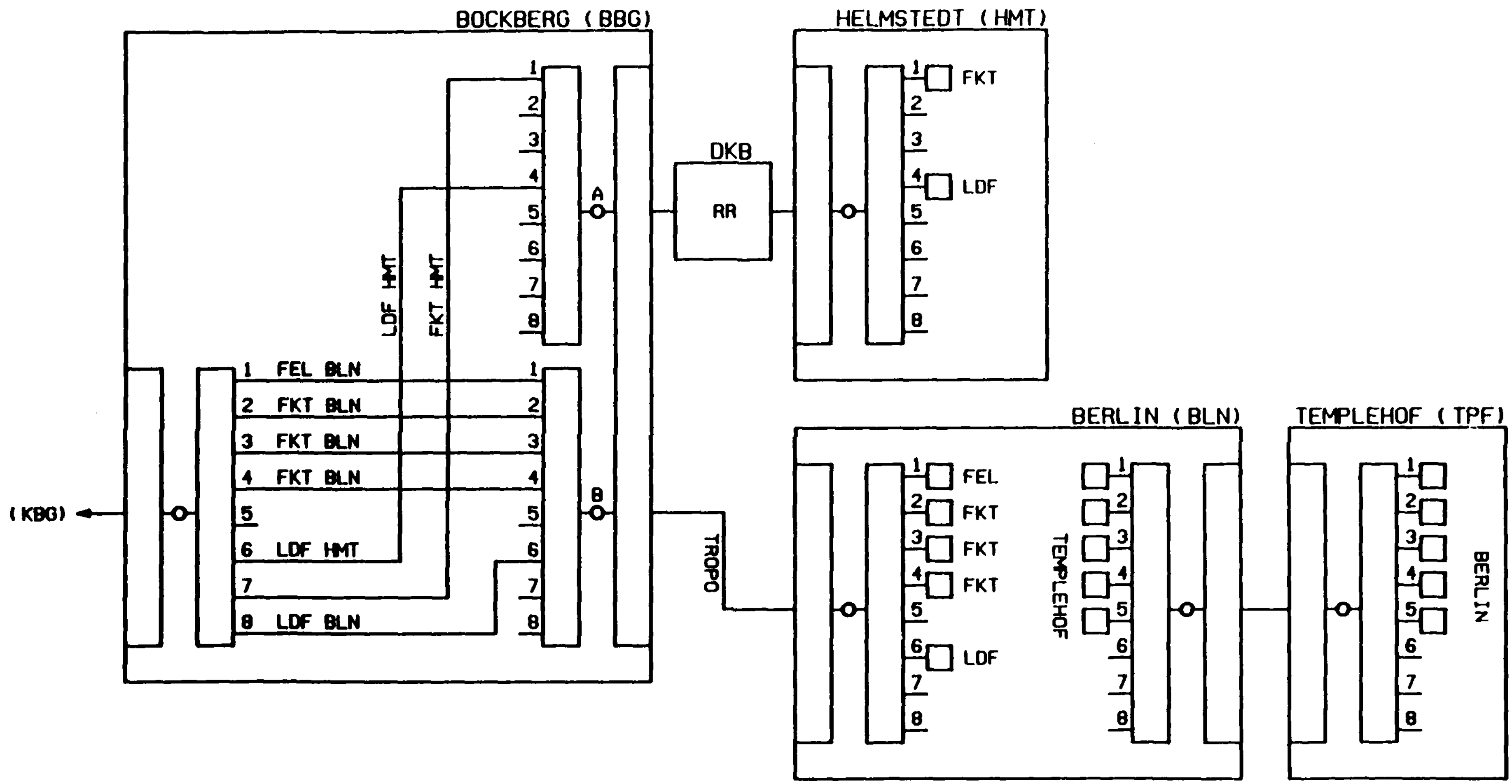

Figure 3. Multiplex Plan for Frankfurt North Phase I. (Sheet 1 of 3)

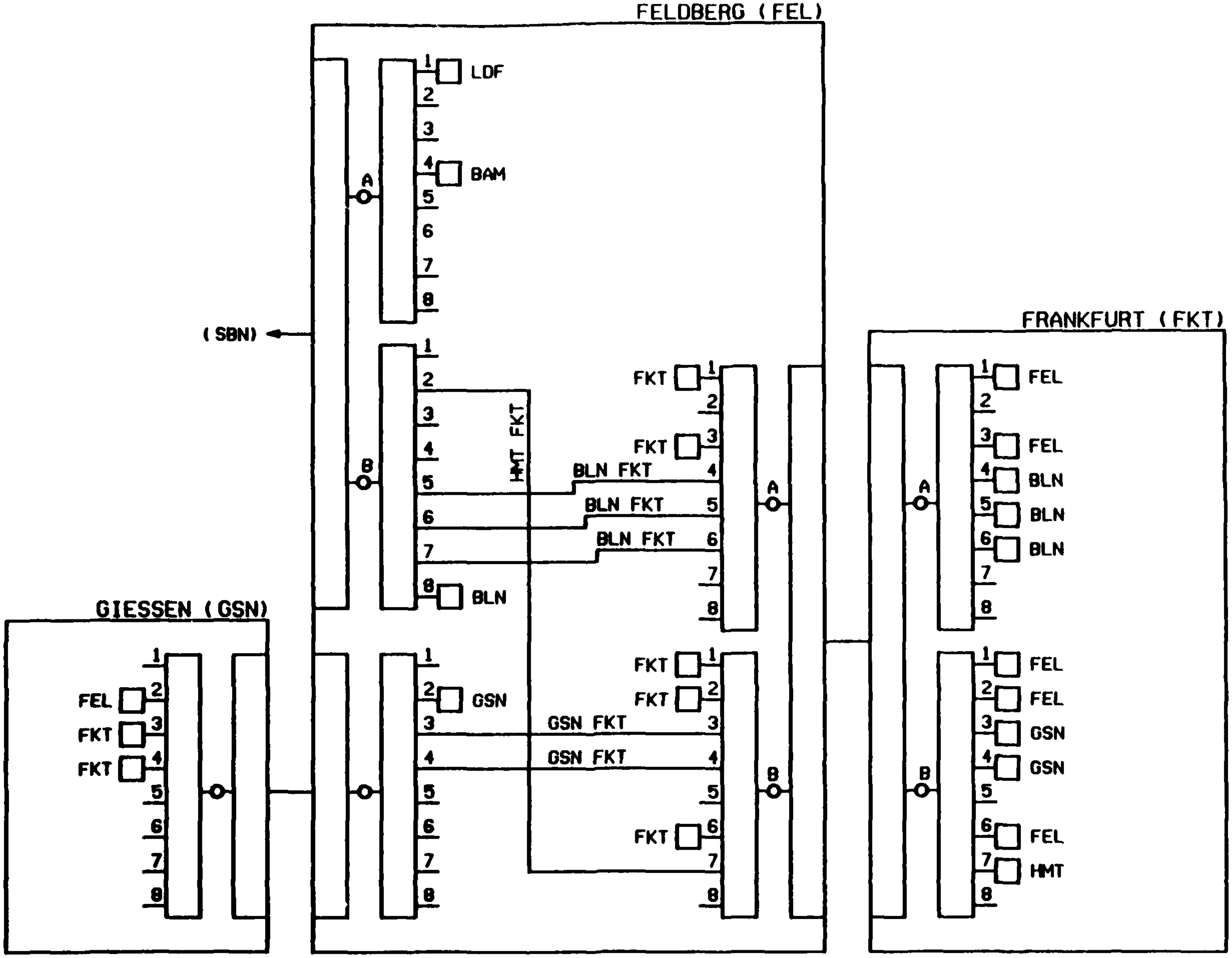

Figure 3. Multiplex Plan for Frankfurt North Phase I. (Sheet 2 of 3)

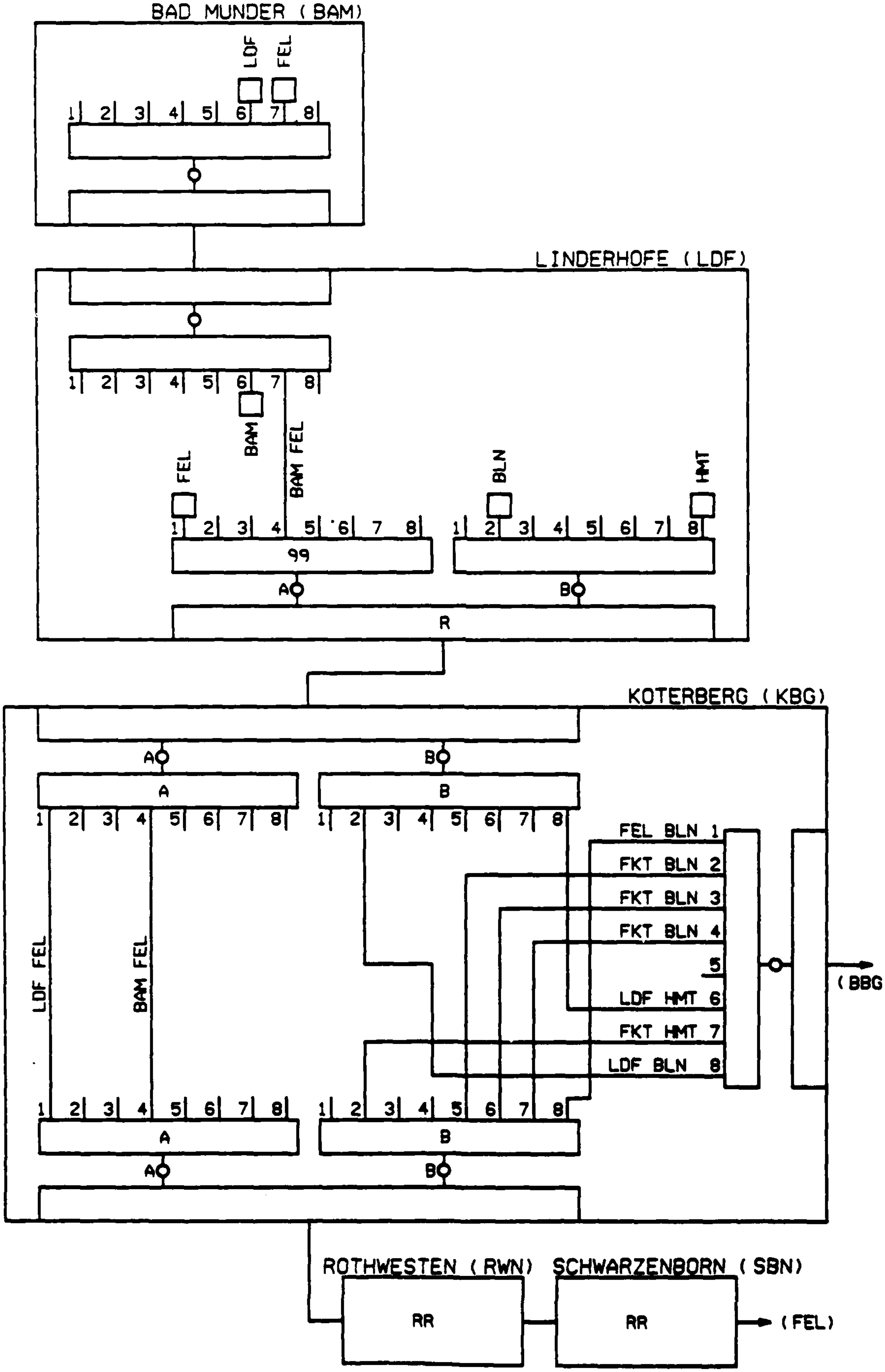

Figure 3. Multiplex Plan for Frankfurt North Phase I. (Sheet 3 of 3)

IV. TIMING ALTERNATIVES FOR THE FRANKFURT NORTH PHASE I NETWORK

1. DESCRIPTION

In order that the transmission availability objectives of the DCS are maintained, the equipment providing timing rates above 1.544 MHz must provide redundant output modules. This redundancy is required for the timing equipment to maintain a mean time between failure performance equal to that of the transmission equipment. Built-in redundancy exists in the transmission hierarchy at and above the AN/FCC-99. Several alternatives exist for providing the appropriate timing interface for the Frankfurt North Phase I Network. Each alternative will be discussed separately with a final recommendation and prioritization of alternatives provided.

For all alternatives, the two tropo sites will use the LORAN-C station clock to provide a 5 MHz frequency standard to the tropo radio. The tropo modem derives the mission bit stream rates from the 5 MHz standard to permit synchronous operation of all multiplexers (first and second level) associated with the single tropo link. The difference in alternatives lies in the methods of timing for the LOS links of FKN Phase I.

2. PLESIOCHRONOUS TIMING

Plesiochronous means near-synchronous and implies that the clocks at the various transmission nodes are sufficiently accurate that the accumulated phase difference can be accommodated in a reasonably sized buffer, typically intrinsic to the transmission equipment. Since the clocks have slightly different rates, the buffer will eventually over or under flow and data will be lost until the buffer is reset to its midpoint and synchronization reacquired. When data bits are lost or added and not accounted for, the circuit will lose bit count integrity (BCI).

Plesiochronous timing hinges on the proper operation of the station clock and clock distribution subsystem (CDS). Initial testing of the station clock and clock distribution subsystem raised a number of questions concerning the required performance of the CDS. [8] In the final analysis, these CDS deficiencies appear to have been corrected; however, the CDS performance will continue to be monitored to ensure compliance with DCS requirements.

3. HYBRID TIMING

The second timing alternative available for use in the Frankfurt North Phase I Network can be described as a hybrid, using a combination of plesiochronous and asychronous operation for LOS links. Using a stable 1.544 MHz (potentially available from the CDS) frequency input to the FCC-98, plesiochronous operation of the FCC-98 level of the digital hierarchy is provided throughout the network. Clock signals can then be cascaded to the transmission equipment in the lower level of the hierarchy (e.g., AN/FCC-100) to allow plesiochronous operation at rates of 1.544 Mb/s and below. The AN/FCC-99 will be operated in the asynchronous (or pulse stuffing) mode, using a strapping option on each port card, which will eliminate the need for

generating clock frequencies at the higher mission bit rates. This option would require the CDS to provide only rates of 1.544 MHz and below, which would reduce the amount of modification required for fielding of the CDS.

4. LOOPED TIMING

In this arrangement, one (or more) site(s) within the network is provided a station clock capability and is designated as the master(s). The other sites derive their timing from the remote master location via the mission bit stream. This arrangement is referred to as looped or slaved timing. It is usually necessary to designate more than one location in a network as a master, to provide a back-up capability in the event of a failure of a master station timing source.

Two sites within the Frankfurt North Phase I Network (Bocksberg and Berlin) will have station clocks. Unless the 12.928 MHz frequency can be provided by the station timing source, Bocksberg would have no capability for meeting the LOS timing requirements because the available 9.696 MHz frequency cannot be used for the 12.928 MHz LOS requirements. The only other way to use the clock located at Bocksberg as the master clock source would be to use the 1.544 MHz digroup level clock. However, no digroup level multiplexer exists at Bocksberg to allow synchronization at the digroup level; therefore, only Berlin can be designated as a master network timing source. This arrangement will result in unacceptable system BCI performance because it relies exclusively on one source (Berlin) for maintaining synchronous operation. Even if one master timing source were acceptable, Berlin in interconnected with the majority of the network (all sites except Templehof) via a troposcatter path which is susceptible to deep fading. Thus, during periods of severe troposcatter fades, loss of clock signals would occur throughout the network causing system failure. This occurrence will be more frequent during dual diversity rather than the normal quad diversity operation. The same result would occur on a more limited scale should one of the tandem line-of-sight links fail due to fading or simple equipment failure. For these reasons looped timing is not recommended.

5. ASYNCHRONOUS TIMING

The asynchronous timing mode interface is characterized by independent data streams that have been derived from different clock sources, so that their significant instants do not necessarily coincide. A process known as pulse stuffing must be used to synchronize each of the channel signals to a common clock reference. Once this process has been performed, the channel signals may be synchronously multiplexed, again maintaining the plesiochronous characteristics of the network.

Pulse stuffing is the operation by which identifiable extra pulses (bits) are added to the data stream to convert a varying input bit rate to a slightly higher but fixed output bit rate. The identifiable stuff bits are inserted into the transmitted bit stream and are recovered in the demultiplexer output at the distant site. At the demultiplexer, the received bit stream is

demultiplexed into parallel syncrhonization and data channels. Each data channel is fed into a buffer minus the stuffed pulses and read out of the buffer by an internal phase-locked voltage-controlled oscillator. Pulse stuffing compensates for the slight differences between the data source clock and the internal multiplexer clock which arise due to clock inaccuracies and instabilities. However, if the receive end of the transmission path does not properly decode the stuff bit due to transmission errors in the stuff code, a loss of bit count integrity in the associated channel will occur. Another disadvantage of this asynchronous operation in pulse stuffing jitter caused by the removal of the stuffed bits at the demultiplexer.

This timing alternative would eliminate the CDS concerns as discussed previously because there would be no clock distribution subsystem required. However, the bit count integrity requirements would not be met. This is due to the fading characteristics of the troposcatter path. The Bocksberg-Berlin link will occasionally operate at a mean signal-to-noise ratio of less than 8dB [6]. At this level the bit count integrity performance of digroups traversing AN/FCC-99 multiplexers would not meet the requirements stated in section II, due to pulse stuffing word errors, as indicated in references 4, 5 and 6. For these reasons, asynchronous operation should be considered as only an interim solution for providing timing for the Frankfurt North Phase I Network.

V. RECOMMENDATION

The timing alternatives for the Frankfurt North Phase I (FKN) can be presented using a prioritization scheme. The most palatable alternative is to configure the network in a plesiochronous mode using the corrected CDS. This necessitated a number of CDS changes, followed by testing in a systems environment and then a reevaluation of the CDS for application within the DCS.

The hybrid option for providing accurate timing for the FKN could be considered on an interim basis. This option allows plesiochronous operation at rates of 1.544 MHz and below, and would therefore provide ne synchronous interface required for the implementation of the AN/FCC-100. This would reduce the amount of initial modification required for fielding the CDS. However, by operating the transmission equipment at the AN/FCC-99 level and above in the asynchronous mode, transmission induced pulse stuffing errors may occur, causing degraded system performance.

Although FKN performance would be degraded, asynchronous operation as described in section IV could be considered as a possible timing alternative. This timing alternative would preclude the tandeming of the AN/FCC-100 synchronous channels and would allow operation only at the 50 kb/s aggregate rate. Again, due to pulse stuffing errors inherent to asynchronous operation, this timing alternative should be considered as only a last resort should the other alternatives fail.

Looped timing is not recommended, because only one site in the system (Berlin) is available for designation as a master timing site, and because this looped timing connectivity would traverse a troposcatter path.

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[6] DCEC EP 4-79, "Linderhof-Bremerhaven, Bocksberg-Berlin Digital System Performance Analysis," May 1979.

[7] DCEC EP 3-83, "DCS Network Synchronization Design Criteria," May 1984.

[8] Naval Electronics Systems Engineering Activity Draft Test Report, "Interface Testing Between the Drama System and a Timing Synchronization System", Feb. 1985.

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